Aura OMI/MLS Measurements of Tropospheric O_3 From MJO to El Nino Timescales: Comparisons with MLS Tropospheric H_2O

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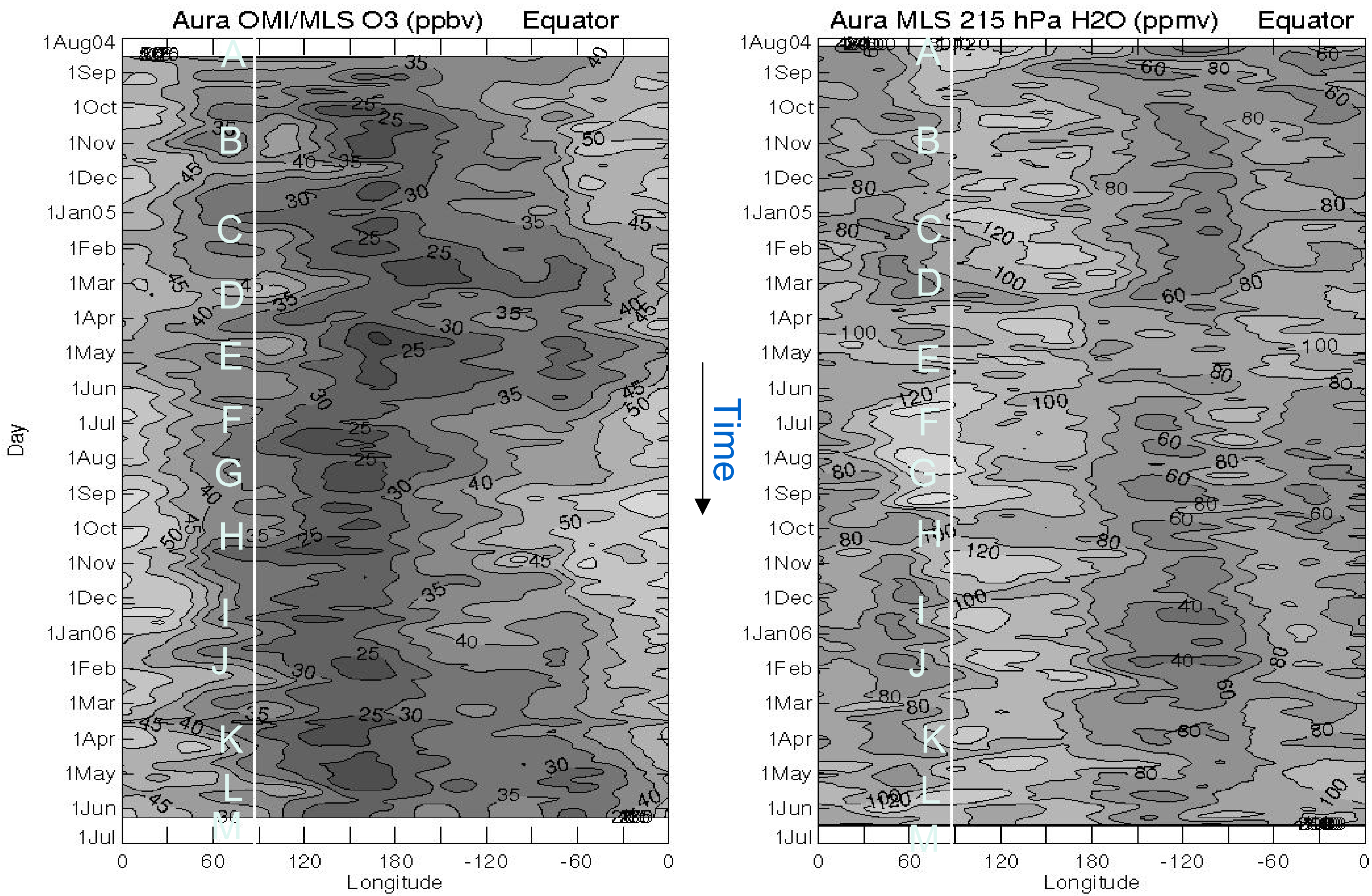
What is the Madden-Julian Oscillation (MJO)?

1. ~40-50 day oscillation in tropospheric winds, temperature, and pressure in the tropics

2. Associated with large-scale circulation/convection in the tropical troposphere

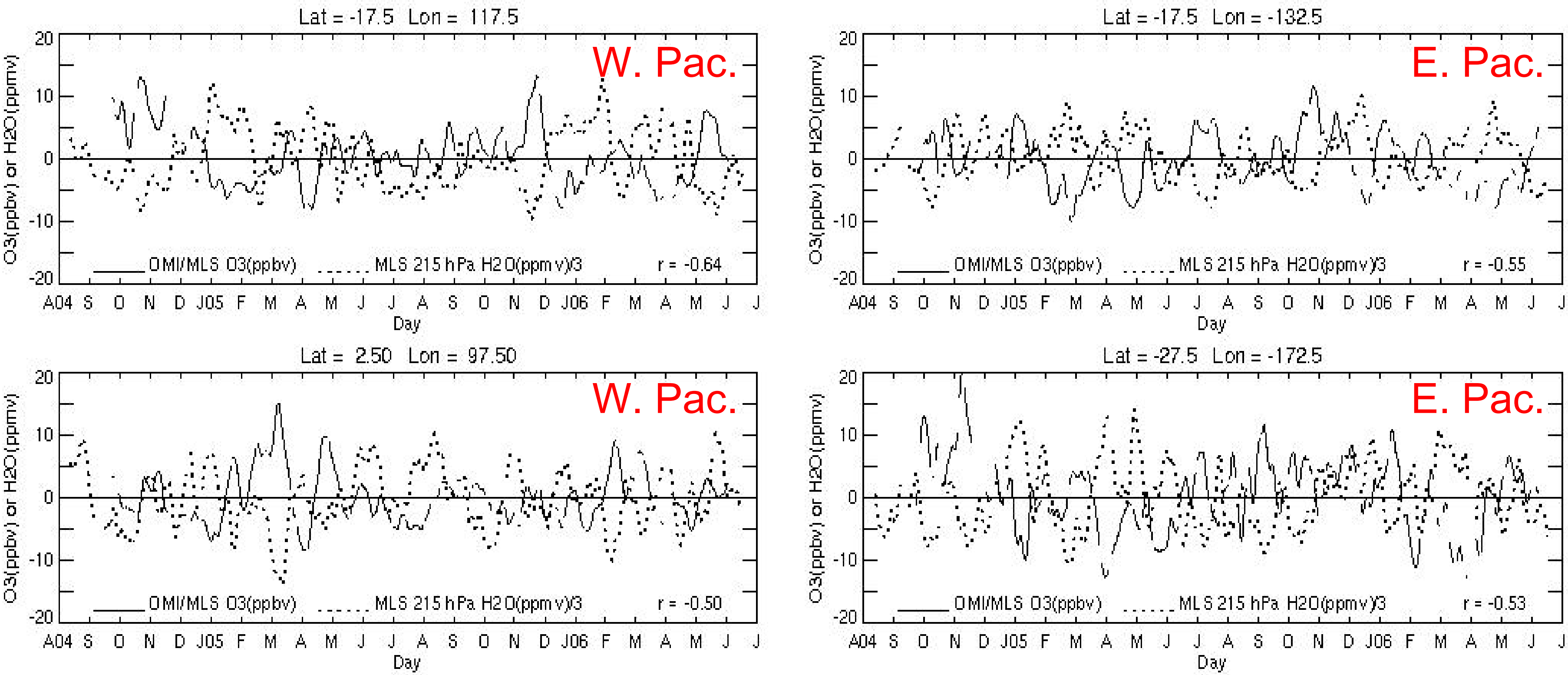
3. Originates primarily in the equatorial Indian Ocean and extends to at least the central Pacific

Tropospheric O_3 and H_2O Time Series are Anti-correlated for Intra-seasonal Time Scales



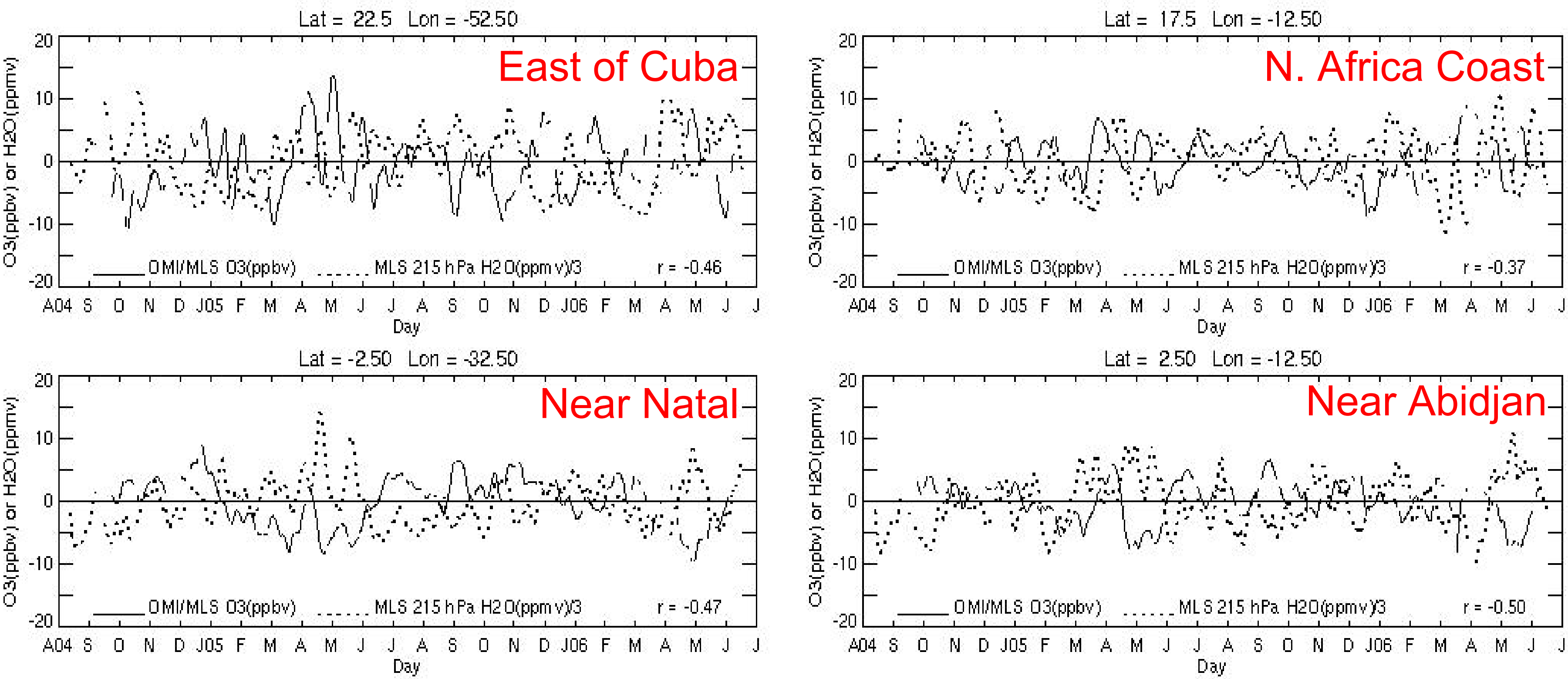
(20-d Lowpass Filter)

Tropical Pacific: Intra-Seasonal Time Series of OMI/MLS Tropo O3 (ppbv) and MLS 215 hPa H2O (ppmv)



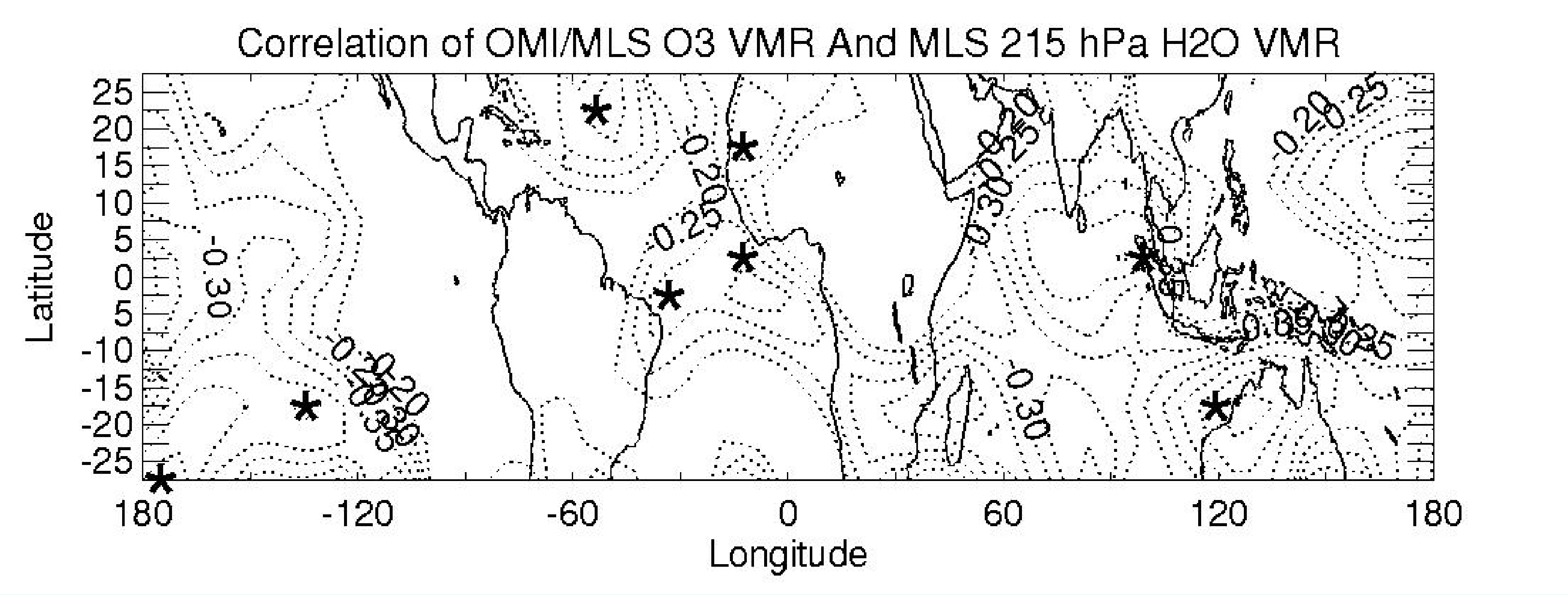
(20-180 d Bandpass Filter)

Tropical Atlantic: Intra-Seasonal Time Series of OMI/MLS Tropo O3 (ppbv) and MLS 215 hPa H2O (ppmv)



(20-180 d Bandpass Filter)

Intra-Seasonal Correlations Between OMI/MLS Tropo O3 and MLS 215 hPa H2O in Tropical Latitudes



95% : |r| > 0.21
99.9%: |r| > 0.34

Time series: 20-180 d Low-pass Filter

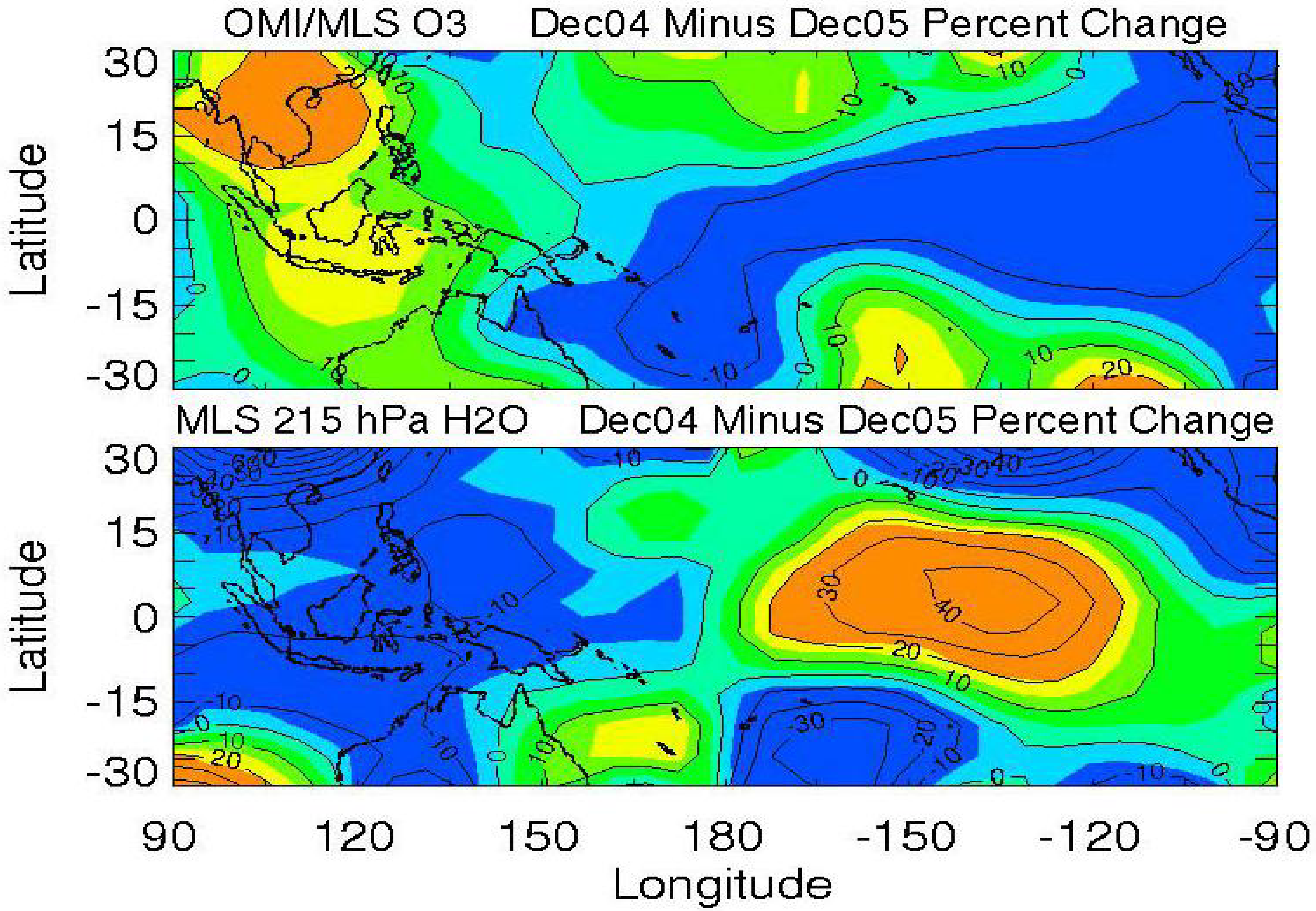
What is El Nino?

1. Occurs when SST in NINO 3.4 region (120^o-170^{o}W, 5^{o}S-5^{o}N) is > 0.5^{o}C above normal for several consecutive months

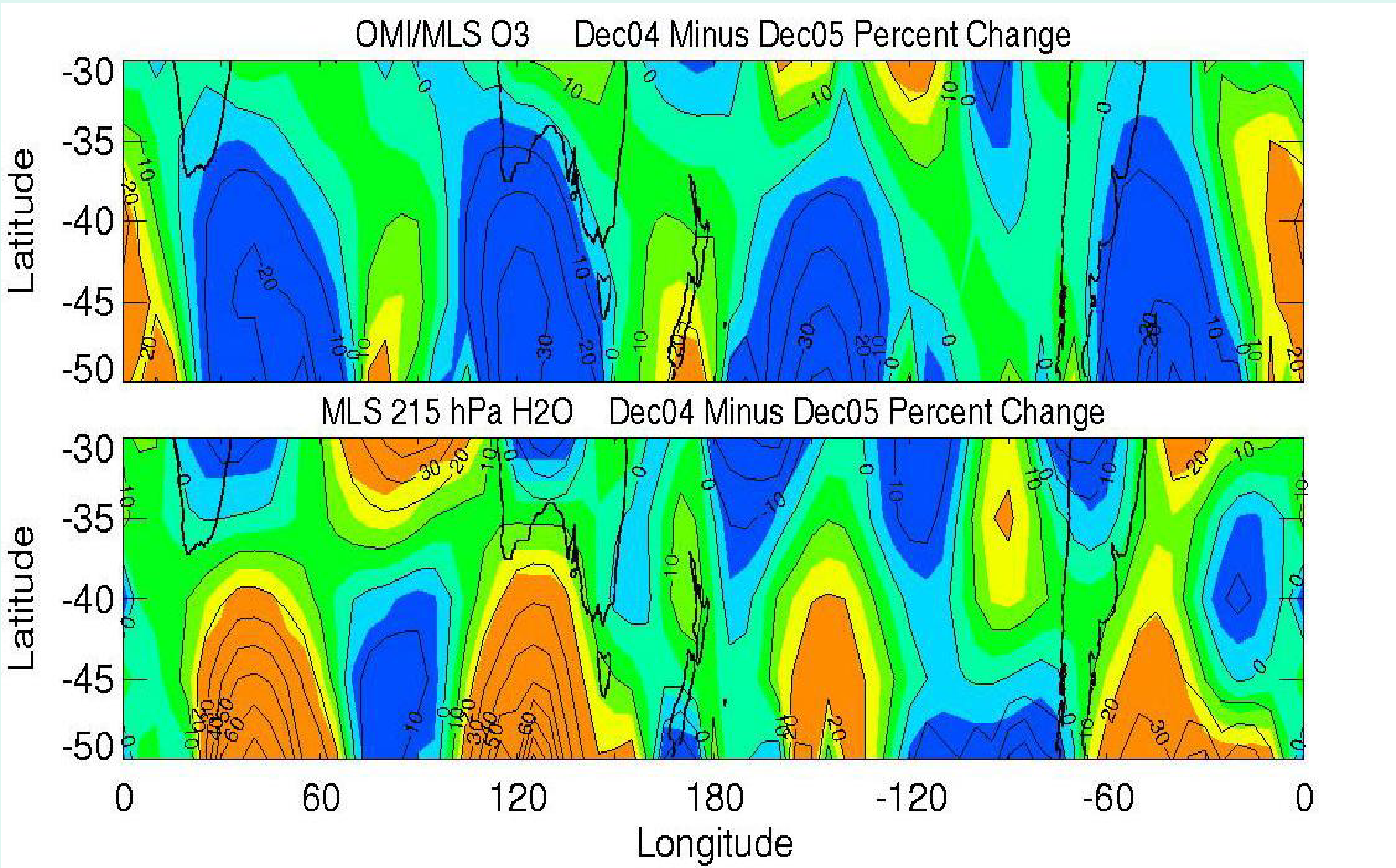
2. Causes shift in tropical convection from western Pacific to eastern Pacific

3. Generally opposite conditions exist during La Nina

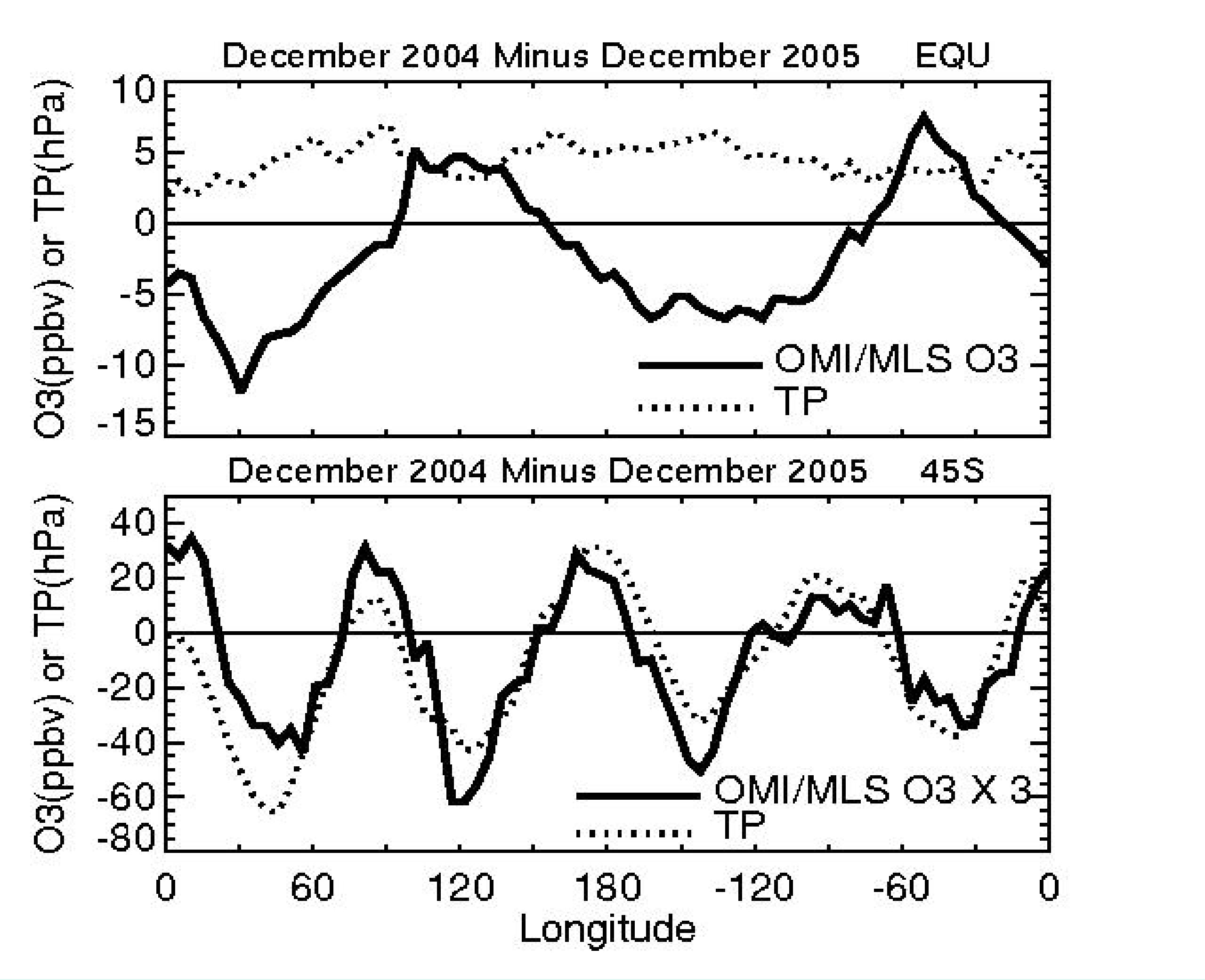
El Nino Effect on Tropospheric O3 and H2O in the Tropics



El Nino Effect on Tropospheric O3 and H2O in the Southern Hemisphere Mid-latitudes



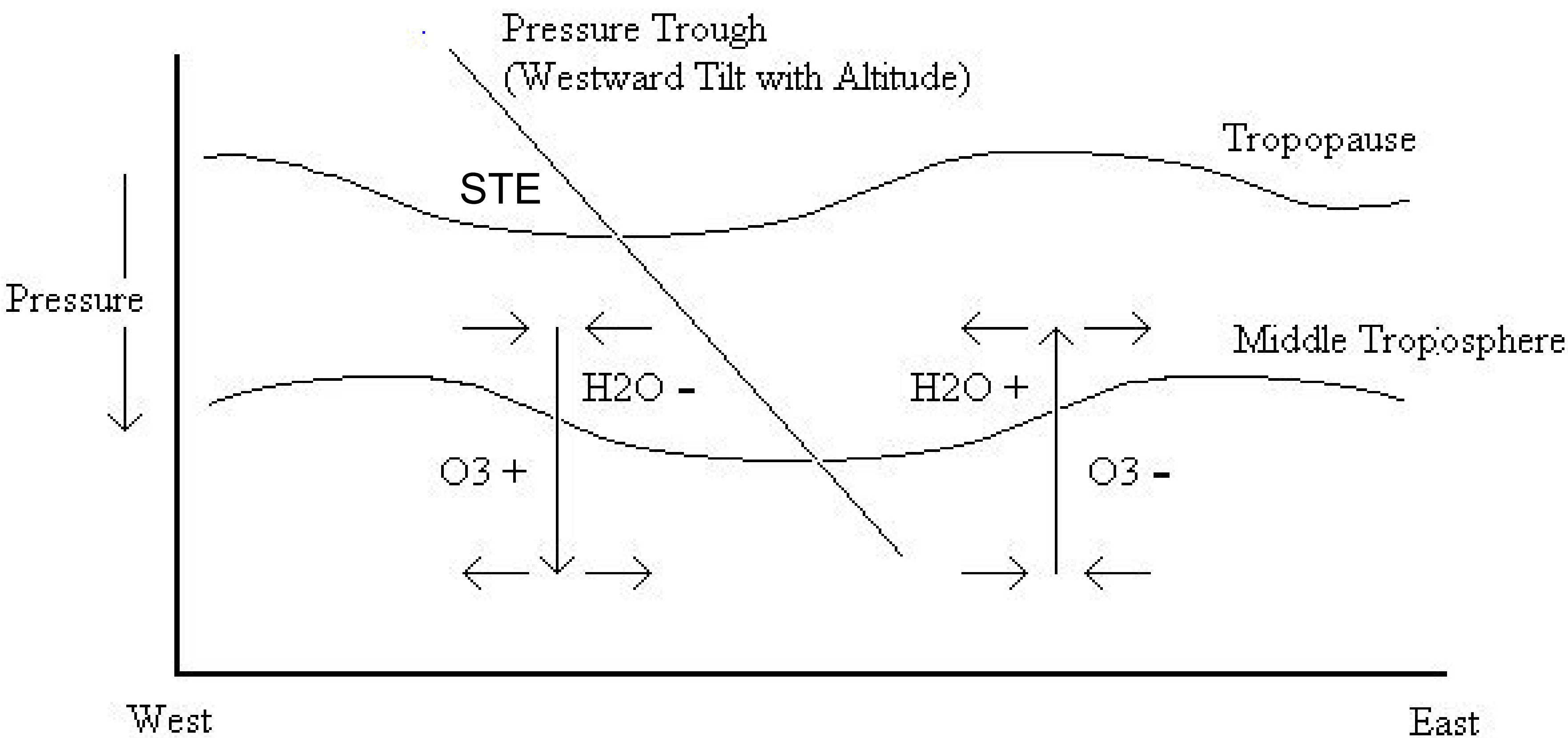
Related Changes in Tropospheric Ozone and Tropopause Pressure



Dec 2004:
El Nino

Dec 2005:
non-El Nino

Baroclinic Instabilities in Mid-Latitudes and Effects on Tropospheric Ozone and Water Vapor



Summary

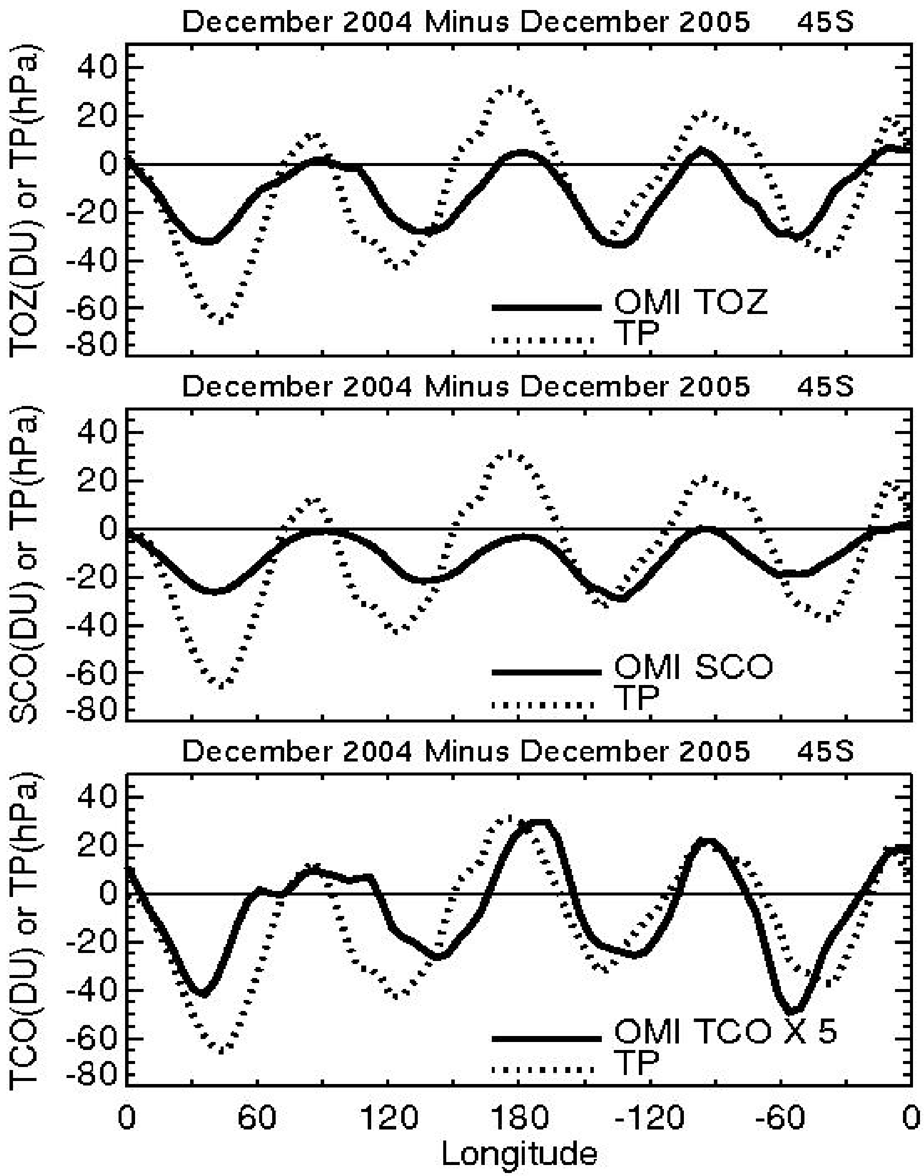
(1) Intra-seasonal (i.e., ~1-2 month) variability in O_3 and H_2O exists throughout the tropics, not just the Pacific/Indian Ocean MJO.

(2) O_3 and H_2O are anti-correlated on intra-seasonal timescales throughout the tropics – suggests convectively-driven lifting/subsidence of tropospheric air mass as the source

(3) 2004 El Nino was weak event, yet produced an east-west "dipole" about the dateline in tropospheric O_3 and H_2O (with O_3 anti-correlated with H_2O)

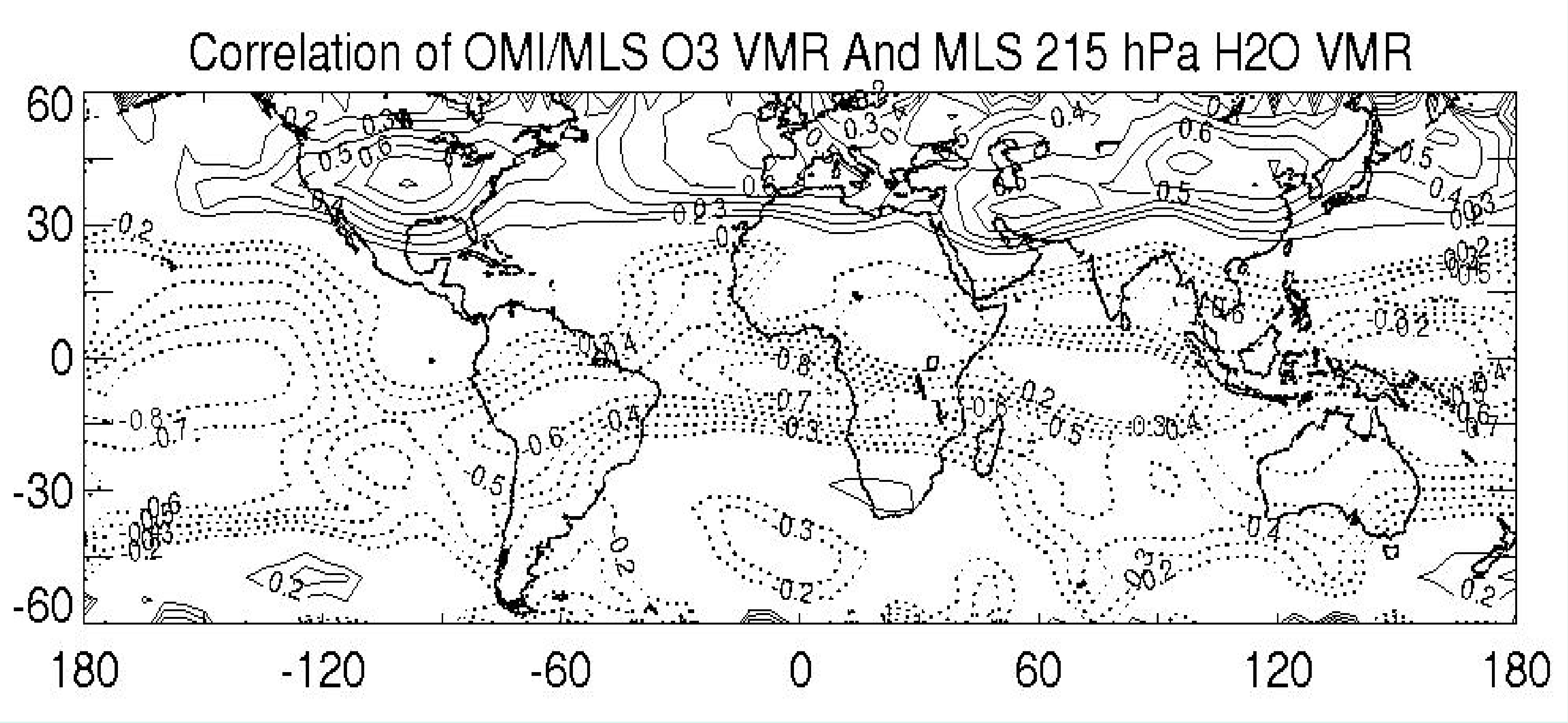
(4) Changes in tropospheric O_3 are caused mostly by dynamical shift in convection related to El Nino, not biomass burning as was the case for 1997-1998 El Nino

(5) Tropospheric trace gases are highly sensitive to baroclinic wave dynamics and small changes in sea surface temperature



December 2004 Minus December 2005 45S
TOZ(DU) or TP(hPa)
OMI TOZ
TP
December 2004 Minus December 2005 45S
SCO(DU) or TP(hPa)
OMI SCO
TP
December 2004 Minus December 2005 45S
TCO(DU) or TP(hPa)
OMI TCO X 5
TP
40
20
0
-20
-40
-60
-80
0
60
120
180
-120
-60
0
Longitude

Seasonal-Cycle Correlation Between OMI/MLS O3 VMR and MLS 215 hPa H2O VMR



(180-d Low-pass Filter)

Tropical Madden-Julian Oscillation Observed In Aura OMI Reflectivity

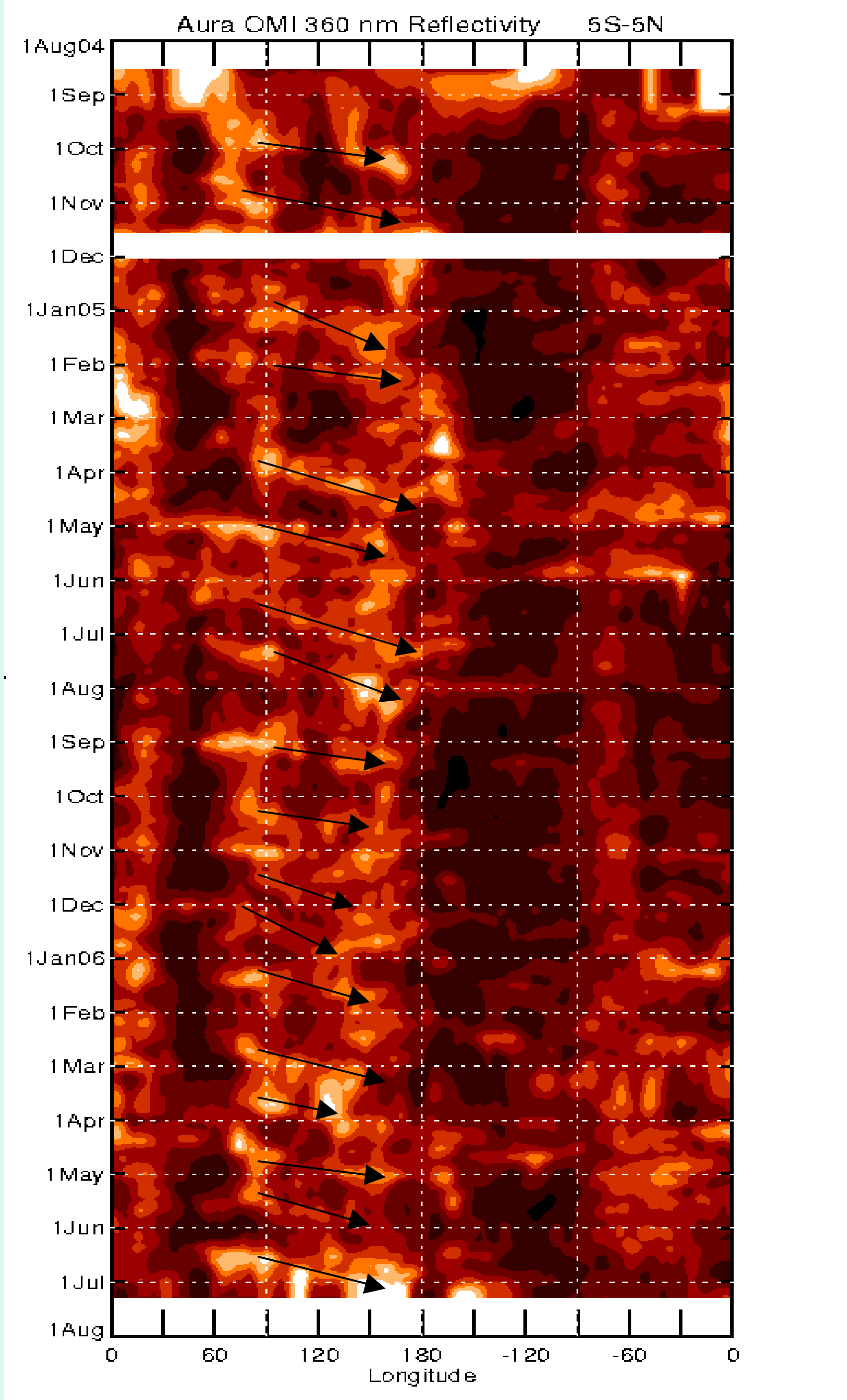
The Madden-Julian Oscillation (MJO):

- Large-scale convection in the tropics

(2) Begins in the Indian Ocean and propagates eastward into the Pacific Ocean across the dateline

(3) Typically ~1-2 month periods

(20-d Lowpass Filter)



TOMS Ozone Weighting Function is Proportional to Pressure Throughout Much of the Troposphere

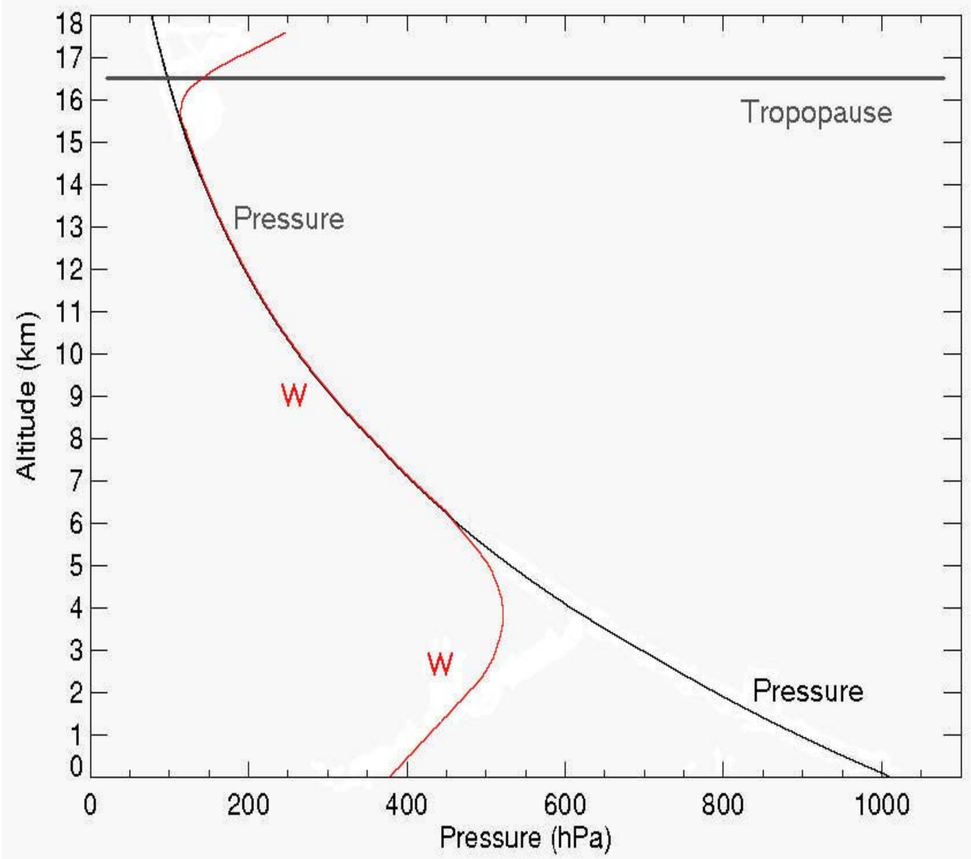
TOMS OZONE ALGORITHM

$$\Delta\Omega \propto \int_{P1}^{P2} \chi \cdot W \cdot d\ln P$$

$$(\Delta\Omega \propto \int_{P1}^{P2} \chi \cdot P \cdot d\ln P)$$

where

$\Delta\Omega$ = Column ozone
P = Pressure
χ = Ozone volume mixing ratio
W = Weighting function (averaging kernel)
C = Constant



Calculation of Column Amount for an Arbitrary Atmospheric Constituent

$\Delta\Omega$ = Column Amount (molecules-m^{-2})

$$\equiv \int_{z1}^{z2} n \cdot dz$$

$$= \int_{z1}^{z2} \chi \cdot n_{ATM} \cdot dz$$

$$= \int_{P1}^{P2} \chi \cdot n_{ATM} \cdot \frac{dP_{ATM}}{\rho_{ATM} g}$$

$$= \frac{N_A}{\mu_{ATM}} \int_{P1}^{P2} \chi \cdot \frac{dP_{ATM}}{g}$$

$$= \frac{N_A}{\mu_{ATM} < g >} \int_{P1}^{P2} \chi \cdot dP_{ATM} = \frac{N_A}{\mu_{ATM} < g >} \int_{P1}^{P2} \chi \cdot P_{ATM} \cdot d \ln P_{ATM}$$

where

z = Altitude (m)
n = Constituent number density (molecules-m^{-3})
n_{ATM} = Atmosphere number density (molecules-m^{-3})
χ = Constituent mixing ratio by unit volume
P_{ATM} = Atmospheric pressure (Pa$\leftrightarrow$N-m^{-2})
ρ_{ATM} = Atmospheric mass density (kg-m^{-3})
g = Acceleration of gravity (m-s^{-2}) ($\approx$9.807 m-s^{-2} at Earth's surface)
μ_{ATM} = Mean molecular weight of atmosphere ($\approx$29)
N_A = Avogadro's number (6.022×10^{26} molecules-kmol^{-1})

Column Amount Also Applies to the Total Atmosphere for Measuring Mass Between Two Pressure Surfaces

For the total atmosphere ($\chi = 1$), $\Delta\Omega$ (molecules - m^{-2})

$$= \frac{N_A}{\mu_{ATM}} \int_{P1}^{P2} \chi \cdot \frac{dP_{ATM}}{g} = \frac{N_A}{\mu_{ATM} < g >} \int_{P_{ATM}=0}^{Psurface} dP_{ATM} = \frac{N_A}{\mu_{ATM} < g >} \cdot P_{surface}$$

$$\text{Mass of atmosphere (kg)} = \oiint_S \Delta\Omega \cdot \frac{\mu_{ATM}}{N_A} \cdot dS$$

$$= \left(\frac{P_{surface}}{< g >} \right)_{\substack{Surface \\ Area \\ Average}} \cdot 4\pi R^2$$

Examples:

Atmospheric mass of Earth: 5.2×10^{18} kg

Atmospheric mass of Saturn's satellite Titan: 9.4×10^{18} kg

(i.e., Titan's atmosphere ~ 80% more massive than Earth's atmosphere)